

The Arthroscopic “Montgolfier Double-Row Knotless” Rotator Cuff Repair Technique

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Abstract: Contemporary arthroscopic double-row suture anchor rotator cuff repairs have superior biomechanics compared with prior iterations. Numerous techniques have been described, but consensus regarding value has yet to be established. We describe an effective and easily reproducible technique: the arthroscopic “Montgolfier double-row” repair technique. This knotless construct has an evenly distributed, load-sharing, radially oriented suture limb configuration much like the envelope cables of a Montgolfier hot-air balloon, its namesake. Other advantages include the ability to apply manual, progressive and calculated tension on each suture limb and easy intraoperative modification depending on tear size, shape, and delamination, as well as tissue tension and quality. Future studies are needed to validate the biomechanics and clinical outcomes of this technique.

Rotator cuff repair techniques have evolved over the past 30 years to improve construct biomechanics and create an environment favorable for tendon-bone healing.¹ Contemporary arthroscopic double-row suture anchor repairs may offer advantages over more traditional techniques.²⁻⁴ These constructs have a high ultimate load to failure and permit maximal contact with the footprint of the greater tuberosity.^{5,6} Nonetheless, anchor placement and suture configuration are reported variably in the literature, and no single technique has been shown to be superior.⁷⁻⁹

In this article, we describe the arthroscopic “Montgolfier double-row” suture anchor rotator cuff repair. The Montgolfier brothers were paper manufacturers from Annonay, France, and are credited as the inventors of the hot-air balloon in the late 18th century.¹⁰ Their design suspended the passenger basket (i.e., the

lateral-row anchors) from the envelope (i.e., the medial-row anchors and corresponding suture through the rotator cuff) with evenly distributed cables). In the shoulder, this design creates a linear suture limb configuration that parallels the distal rotator cuff tendon and permits differential tensioning by location based on tear pattern. In addition, the approach is adaptable because the number of anchors can be modified and the Sugaya repair technique for delaminated tears can be used in combination if needed.¹¹

The Montgolfier double-row technique is versatile, efficient, and easily reproduced. As delivering value (i.e., clinical outcome divided by cost of care) to the patient and health care system becomes increasingly emphasized, techniques for commonly performed procedures that optimize outcomes will be needed.

Surgical Technique

Patient Positioning

The patient arrives in the operating room after receiving an interscalene block in the holding area. He or she is positioned in a semi-inclined beach-chair position on an electric surgical table. General anesthesia is administered after confirmation of adequate clearance of the posterior shoulder. The operative extremity is placed in 3 kg (female patients) or 4 kg (male patients) of suspended traction with the shoulder forward flexed to approximately 30° (Fig 1). The arm is prepared with iodine and draped in the usual fashion. The acromion, coracoid, acromioclavicular joint, coracoacromial ligament, and primary posterior viewing portal are marked with a surgical pen (Fig 2).

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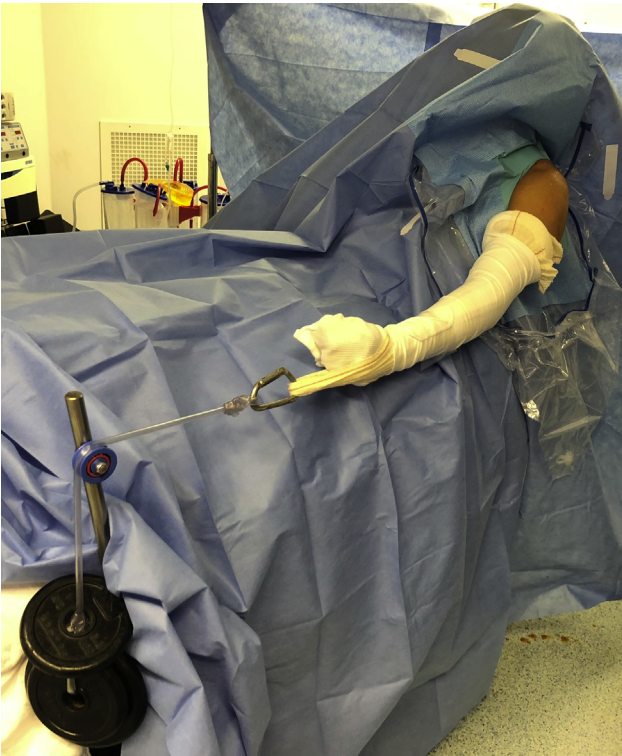


Fig 1. The patient is positioned in a semi-inclined position on an electric surgical table. The operative left upper extremity is suspended with traction in approximately 30° of forward flexion.

Diagnostic Arthroscopy

Table 1 shows the pearls and pitfalls of the described technique. Initially, a standard posterior viewing portal is created 2 cm inferior and 2 cm medial to the posterolateral border of the acromion. The arthroscope is introduced into the glenohumeral joint, and a diagnostic arthroscopy is completed. Just lateral to the tip of the coracoid and under direct visualization with a spinal needle, a standard anterior portal within the rotator interval is established. The arthroscope is then repositioned into the subacromial space, and a spinal needle is used to localize a midlateral portal. A subacromial bursectomy is performed to clear soft tissue from the anterior, lateral, and posterior gutters. The undersurface of the acromion is debrided, and the acromial attachment of the coracoacromial ligament is released. An acromioplasty and lateral acromial shortening are performed as necessary to create more space for instrumentation to effectively perform the rotator cuff repair (**Fig 3**).

Rotator Cuff Repair

The arthroscope is moved to the midlateral portal for an “on top of the mountain” view of the rotator cuff. An accessory working portal 2 cm anterior to the anterolateral border of the acromion is established with

a spinal needle. The rotator cuff tear pattern and mobility are assessed with a tissue grasper. All remaining soft tissue impeding visualization and/or mobilization of the rotator cuff is removed. A tissue biter and shaver are used to debride nonviable tissue and clean the edge of the rotator cuff for repair. The footprint of the greater tuberosity is then debrided of all remaining soft tissue, and an arthroscopic burr is used to prepare the bone bed approximately 5 mm from the articular margin (**Fig 4**).

An additional accessory portal off the edge of the acromion is established after localization with a spinal needle to decrease the “dead man” angle for medial-row anchor insertion. An awl is introduced and advanced with a mallet into the footprint along the axis of the anatomic neck. If a 2 × 2 double-row configuration is planned, then the posterior anchor of the medial row is placed first (**Video 1**). The hole is tapped, and a 5.5-mm BioComposite Corkscrew FT Triple Play Vented suture anchor (Arthrex, Naples, FL) is screwed into place. The suture limbs for this construct are colored white, blue, or white with a black stripe. They are docked through the previously established anterior portal. A 3- or 4-cm PassPort Button cannula (Arthrex) (depending on the size of the patient) is inserted through the anterolateral working portal with a curved hemostat. A Scorpion Suture Passer (Arthrex) is introduced through the cannula, and the first blue suture limb is passed through the most posterior extent of the rotator cuff. A suture grasper is inserted through the posterior portal, and the suture limb is docked posteriorly. This step is repeated 3 more times, alternating between blue and black-striped suture limbs and



Fig 2. The acromion, coracoid, acromioclavicular joint, and coracoacromial ligament of the operative left shoulder, in addition to the posterior viewing portal (arrow), are marked prior to the surgical time-out. (A, anterior; L, lateral; P, posterior.)

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Use the midlateral portal as the primary viewing portal for the best visualization.	There may be a learning curve if prior practice has been limited to viewing the rotator cuff from a posterior portal.
Use an accessory anterolateral portal as the primary working portal with anterior and posterior portals for suture management.	The anterolateral portal may place the cephalic vein at risk if positioned too far distally.
Perform an acromioplasty to improve the space needed for repair, and take time during the subacromial decompression to permit visualization throughout the procedure.	Failure to remove all soft tissue within the anterior, lateral, and posterior gutters will impede visualization and increase surgical time.
Identify the rotator cable, and make every effort to pass the medial-row suture limbs through this tissue to enhance repair biomechanics.	The rotator cable is not always easily defined, particularly if the bursa is not debrided from the superficial rotator cuff.
Evenly distribute the suture limbs from posterior to anterior, and alternate colors for suture management while using the anterior and posterior portals for docking.	Failure to manage sutures can lead to confusion and added surgical time. A system should be in place to proceed through the repair the same way every time.
Manually judge tension for each suture limb independently based on tear size and shape.	

sequentially passing the sutures through the rotator cuff repair site at approximately equidistant positions moving anteriorly. Once all 4 suture limbs are docked through the posterior portal, they are clamped (Fig 5). In the case of a 2×2 double-row configuration, the anterior anchor of the medial row is then put into place following the same steps described earlier but the sutures are initially docked posteriorly. The sequence of passing suture through the rotator cuff is repeated moving from posterior to anterior, and the suture limbs are docked anteriorly with each pass for suture management. The remaining white suture of both anchors is then removed.

In a 2×2 double-row configuration, the 4 suture limbs from the posterior, medial-row anchor are positioned with a suture grasper through the anterolateral portal onto the greater tuberosity to judge the appropriate excursion and tension on the rotator cuff for lateral-row anchor placement. The greater tuberosity is then debrided at that site, and the suture limbs are brought out through the anterolateral cannula. The sutures are loaded into the eyelet of a 5.5-mm Bio-Composite SwiveLock C Closed Eyelet suture anchor (Arthrex). An awl is advanced with a mallet into the greater tuberosity in the desired position for the

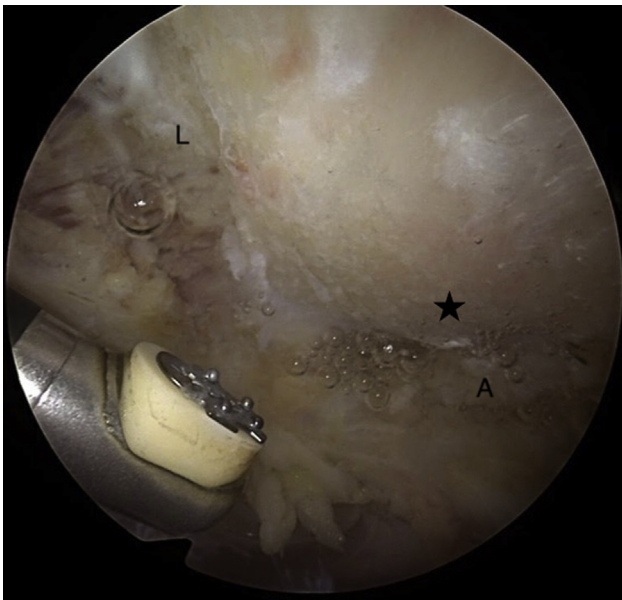


Fig 3. Intraoperative arthroscopic image of the left shoulder in the beach-chair position through a posterior viewing portal in the subacromial space after subacromial decompression, acromioplasty (star), and lateral acromial shortening. It should be noted that the radiofrequency device is being used through the midlateral portal. (A, anterior; L, lateral.)

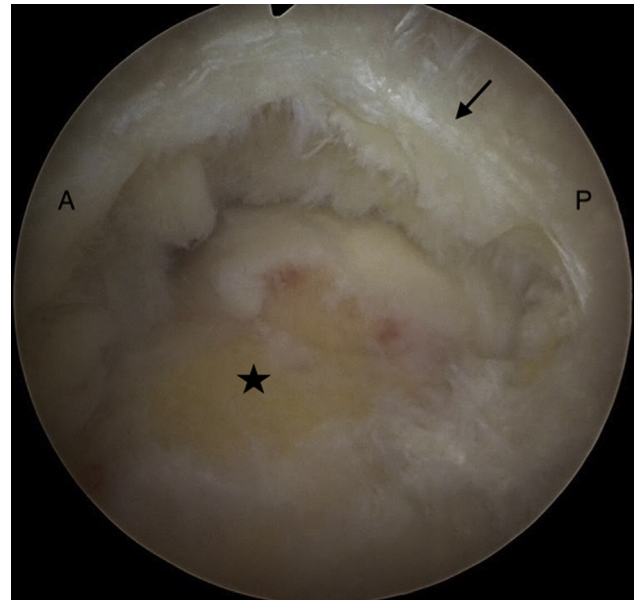


Fig 4. Intraoperative arthroscopic image of the left rotator cuff in the beach-chair position viewed through the midlateral portal after debridement (arrow) to determine tear size and shape. The underlying bone bed of the greater tuberosity footprint (star) has been prepared to enhance tendon-bone healing. (A, anterior; P, posterior.)

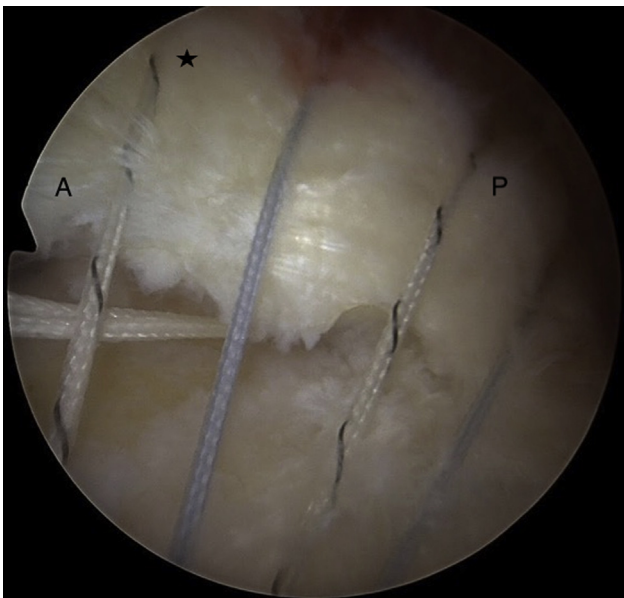


Fig 5. Intraoperative arthroscopic image of the left shoulder in the beach-chair position through a midlateral viewing portal showing 4 equidistant suture limbs from a medial-row anchor that have been passed through the left rotator cuff (star) at the level of the rotator cable. The sutures are currently docked in the anterolateral working portal. (A, anterior; P posterior.)

posterior, lateral-row anchor. The eyelet introducer on the anchor is sunk into the hole until the bottom of the anchor is flush with the bony surface. Each of the suture limbs is manually tensioned under direct visual control, and the suture anchor is then screwed into place (Fig 6). For a 2 × 2 double-row configuration, the process is repeated by bringing the suture limbs from the anterior, medial-row anchor down to an anteriorly placed, lateral-row anchor.

Postoperative Rehabilitation

The patient is placed in a sling with a 20° abduction pillow for 4 weeks. Five days after surgery, the patient starts a stepwise, detailed, home-directed self-stretching exercise program with or without hydrotherapy. After 4 weeks, the abduction pillow is removed and a regular sling is used for 2 more weeks. There is no specific strengthening program. The patient can expect to return to activities of daily living 3 months after surgery, and full activities are permitted at 6 months postoperatively.

Discussion

Arthroscopic double-row rotator cuff repair has been popularized by the ability to restore the anatomic footprint and increase the contact area for healing.¹ Initial open and arthroscopic techniques involved creation of transosseous tunnels through the greater tuberosity but proved technically challenging and

time-consuming.^{2,3} In 2006, Park et al.⁴ described a transosseous-equivalent repair in an attempt to replicate the mechanical forces across the construct seen after traditional open transosseous repair. Biomechanical studies of this technique later proved its superiority, and double-row repairs with suture anchors remain prevalent.^{5,6}

This article details a double-row suture anchor repair that may provide advantages to the surgeon over prior iterations with suture anchors (Table 2).⁷⁻⁹ The suture bridge technique, for example, was developed to optimize coverage of the footprint by crossing sutures over the repaired rotator cuff.^{4,7} This contrasts with the linear suture configuration of the Montgolfier double row, which remains parallel to the long axis of the rotator cuff tendon and its medial blood supply.¹² This technique also maximizes the completeness of rotator cuff repair, but previous work has questioned whether this factor reduces the risk of retear.¹³ In addition, the current technique was developed in part because of the medial-row failures seen with suture bridge repairs at the musculotendinous junction.^{14,15} Squeezing the tendon down to the footprint by knot tying at the medial row may have contributed to these failures.¹⁶ The simple passage of suture without knots described in this article may avoid creating medial zones of necrosis. Furthermore, gentle manual tightening of suture down to the lateral row under visual control to complete the double row is less likely to compromise the tenuous blood supply of the distal tendon and create ischemia.¹⁶⁻¹⁸

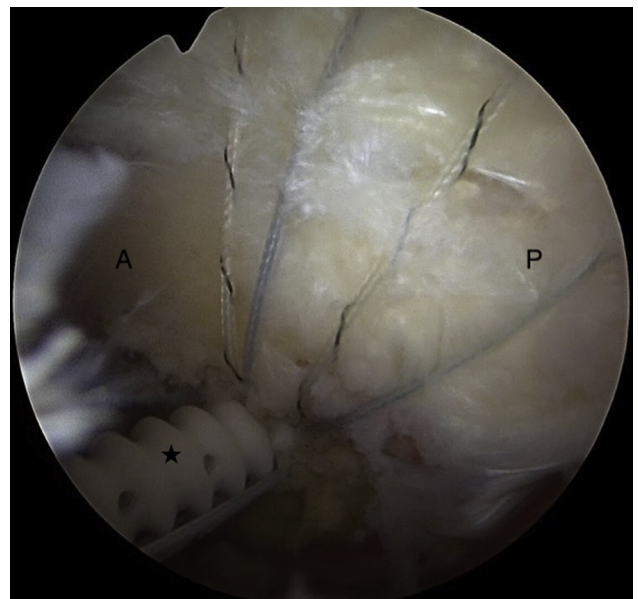


Fig 6. Intraoperative arthroscopic image of the left shoulder in the beach-chair position through a midlateral viewing portal showing the insertion of a lateral-row anchor (star) in the shoulder. The suture limbs resemble the cables of a Montgolfier hot-air balloon. (A, anterior; P, posterior.)

Table 2. Advantages and Risks and/or Limitations

Advantages	Risks and/or Limitations
Equally distributed, linearly oriented suture limbs that do not cross radial blood supply of rotator cuff	
Individual and differential manual tensioning of each suture limb under visual control based on tear characteristics	No biomechanical data are available for this particular technique.
Knotless construct that is fast and efficient and obviates arthroscopic knot tying and squeezing effect on tendon	Failure of the medial- or lateral-row anchor will cause failure of the entire construct.
Easy combination with Sugaya technique for delaminated tear and/or modified Mason-Allen sutures for enhanced fixation	

Another significant benefit is the versatility of the Montgolfier double-row technique based on tear size, shape, and delamination, as well as tissue tension and quality. The number of medial-row anchors can vary and ranges from 1 to 3 depending on tear size. The distribution of evenly spaced medial-row suture limbs can be adjusted based on tissue tension and tear shape. The Sugaya repair technique for commonly encountered delaminated tears can easily be used in combination.¹¹ Furthermore, to enhance fixation of the rotator cable at the leading edge of the supraspinatus, a modified Mason-Allen suture technique can be used in conjunction with this technique, similarly to a rip-stop suture.^{8,19}

Pitfalls of the Montgolfier double-row technique are highlighted in Table 1. Similarly to other knotless suture anchor repairs, 1 limitation is that failure of the medial- or lateral-row anchor(s) will cause failure of the entire construct. In addition, recent evidence has shown that double-row repairs are associated with higher visual analog scale scores during the first 3 months after surgery compared with single-row repairs.²⁰ From a biomechanical standpoint, there has not been a study to validate this technique and compare it with other existing double-row suture anchor repairs. Prior work on knotless double-row repairs has suggested early suture loosening after cycling that could affect gap formation at the greater tuberosity bone-tendon interface.²¹ Nonetheless, this technique is reproducible, versatile, and efficient, which has implications on both the learning curve and surgical time. Future studies are needed to validate the biomechanics, economics, and clinical outcomes of this technique to truly evaluate the value it may provide to the patient and health care system.

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